

**CHIYODA THOROUGHbred CT-121 CLEAN COAL PROJECT  
AT GEORGIA POWER'S PLANT YATES**

***PHASE II RESULTS***

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**ABSTRACT**

*The Chiyoda Thoroughbred CT-121 flue gas desulfurization (FGD) process at Georgia Power's Plant Yates completed a two year demonstration of its capabilities in late 1994 under both high- and low-particulate loading conditions. This \$43 million demonstration was co-funded by Southern Company, the Electric Power Research Institute and the DOE under the auspices of the U.S. Department of Energy's Round II Innovative Clean Coal Technology (ICCT) program.*

*The focus of the Yates Project was to demonstrate several cost-saving modifications to Chiyoda's already efficient CT-121 process. These modifications included: the extensive use of fiberglass reinforced plastics (FRP) in the construction of the scrubber vessel and other associated vessels, the elimination of flue gas reheat through the use of an FRP wet chimney, and reliable operation without a spare absorber module.*

*This paper will focus on the testing results from the last trimester of the second phase of testing (high-ash loading). Specifically, operation under elevated ash loading conditions, the effects of low- and high-sulfur coal, air toxics verification testing results and unexpected improvements in byproduct gypsum quality are discussed.*

**I. INTRODUCTION**

The demonstration at Georgia Power's Plant Yates involved the retrofit construction of a CT-121 wet-limestone scrubber to an existing 100 MW pulverized coal-fired boiler. The principle difference between the CT-121 process and more common spray tower-type FGD systems is the use of a single process vessel, Chiyoda's patented Jet Bubbling Reactor® (JBR), in place of the usual spray tower/reaction tank/thickener arrangement. Initial startup of the process occurred in October 1992, and the demonstration project was completed in December 1994. Process operation continues with the CT-121 scrubber as an integral part of the site's Phase I Clean Air Act compliance plan.

Several of the latest evaluations that comprised the CT-121 demonstration project are discussed in this paper. In the last trimester of testing the CT-121 process was operated under moderate-ash inlet loading conditions while process reliability and availability were continuously evaluated. Additionally, exceptional concurrent particulate removal efficiencies were measured under moderate-particulate loading conditions, which was consistent with particulate removal efficiencies observed in earlier measurements under both high- and low-particulate loading conditions.

Parametric testing was also conducted under moderate-ash loading conditions while burning both high- and low-sulfur coals. The data gathered were regressed and multi-variable regression models were developed to provide an accurate prediction of the scrubber's SO<sub>2</sub> removal efficiency under the most likely future operating conditions. As part of the moderate-particulate removal evaluation, limited air toxics measurements were also performed for the second time. The purpose of this additional testing was to evaluate air toxics removal across the CT-121 under elevated ash loading conditions as well as to validate or controvert the findings of an earlier air toxics testing effort that was sponsored by DOE in June of 1993<sup>1</sup>.

A brief discussion of findings on the properties of the gypsum stack (not contaminated with flyash) following one year of dormancy is also included in this paper. An analysis of the chloride content showed that chloride levels in the gypsum decreased over time without any specific action by the project team. This finding increases the possible uses of the unwashed gypsum produced by this process. An indicator of public acceptance was the granting of a Plant Food License to Georgia Power for the non-ash gypsum at Plant Yates, by the State of Georgia's Department of Agriculture in October of 1996.

In general, the Yates CT-121 process performed well, exhibiting excellent SO<sub>2</sub> removal efficiency, particulate removal and consistent reliability. In addition to these successes, several possible process improvements were identified during the demonstration that could improve future designs of an already superior process.

## **II. FACILITY AND OPERATING DESCRIPTION**

The Yates plant site is comprised of seven coal-fired boilers, all Phase I affected units, with a total rated capacity of 1,250 MW. Plant Yates' 100 MW Unit 1 is the source of flue gas for the CT-121 process. All of the flue gas from Unit 1 is treated by the CT-121 wet FGD process with no provision for flue gas bypass. During the low flyash phase of parametric testing in 1992 and 1993, the existing ESP for Unit 1 was used for particulate control. The design efficiency for this ESP is 98%. In March, 1994, the ESP was fully deenergized at the start of high-particulate parametric testing, and partially energized to a target efficiency of 90% between June 1994 and November 1994.

A simplified site diagram for the Yates CT-121 retrofit is presented in Figure 1.

The scrubber demonstration facility equipment can be divided into five major subsystems:

- Boiler / ESP
- CT-121 scrubber / wet chimney
- Limestone preparation circuit
- Byproduct gypsum stacking area
- Process control system.

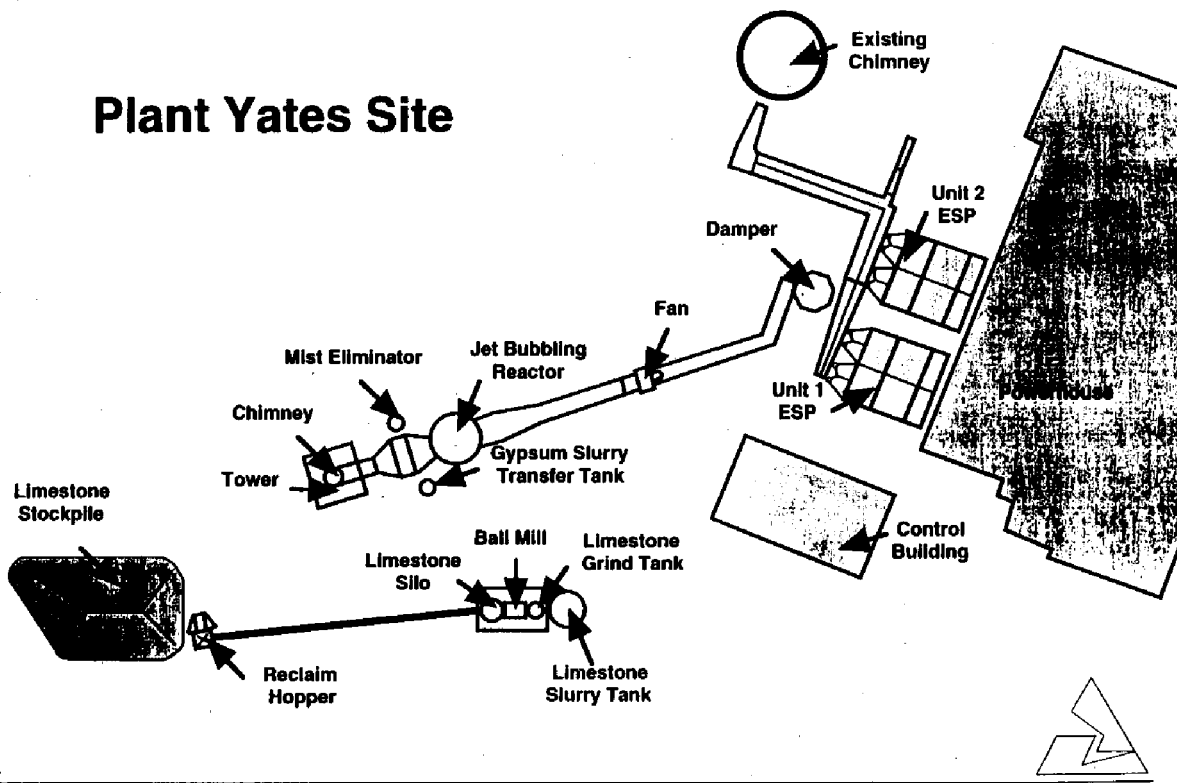
The central feature of the process is Chiyoda's unique absorber design, called a Jet Bubbling Reactor (JBR), which combines concurrent chemical reactions of limestone dissolution,  $\text{SO}_2$  absorption/neutralization, sulfite oxidation, gypsum precipitation and gypsum crystal growth together in one vessel. A cut-away view of the JBR is illustrated in Figure 2. Since much of the undesirable crystal attrition and secondary nucleation associated with the large centrifugal pumps in conventional FGD systems is eliminated in the CT-121 design, large easily dewatered gypsum crystals are consistently produced. This design also significantly reduces the potential for gypsum scale growth, a problem that frequently occurs in natural-oxidation FGD systems.

In the Yates installation (Figure 1), the flue gas enters the scrubber's inlet gas cooling section down-stream of the boiler's induced draft (I.D.) fan. This fan also serve as the scrubber's booster fan. Here the flue gas is cooled and saturated with a mixture of pond water and JBR slurry. From the gas cooling section, the flue gas enters an enclosed plenum chamber in the JBR formed by the upper deck plate and lower deck plate. Sparger tube openings in the floor of the inlet plenum force the inlet flue gas below the level of the slurry reservoir in the jet bubbling zone (froth zone) of the JBR as shown in Figure 3. After bubbling through the slurry, where all the concurrent reactions occur, the gas flows upward through large gas riser tubes that bypass the inlet plenum. Entrained liquor in the cleaned gas disengages in a second plenum above the upper deck plate due to a drastic velocity reduction and the cleaned gas passes to the 2-stage, chevron-style, horizontal-flow mist eliminator, then on to a wet FRP chimney.

“A closed-circuit, wet ball mill limestone preparation system is used to grind raw (3/4x0) limestone. The particle size of the ground limestone is small enough (90% passing a #200 mesh screen) to ensure that it is dissolved easily and that the amount of unreacted limestone in the JBR can be minimized or eliminated.

The JBR slurry reservoir provides about 36 hours of solid-phase residence time, depending on the  $\text{SO}_2$  pick-up rate. The slurry from the JBR is pumped intermittently to a gypsum slurry transfer tank (GSTT) for JBR slurry level control and slurry density control. In the GSTT, the slurry is diluted for pumping to a Hypalon®-lined gypsum (or gypsum/ash) stacking area for gravity dewatering and storage. Gypsum stacking is a disposal technique that involves filling a diked area with slurry for gravity sedimentation. Over time, this area fills with settled solids. The filled area is then partially excavated to increase the height of the containment dikes. The repetitive cycle of

## Plant Yates Site



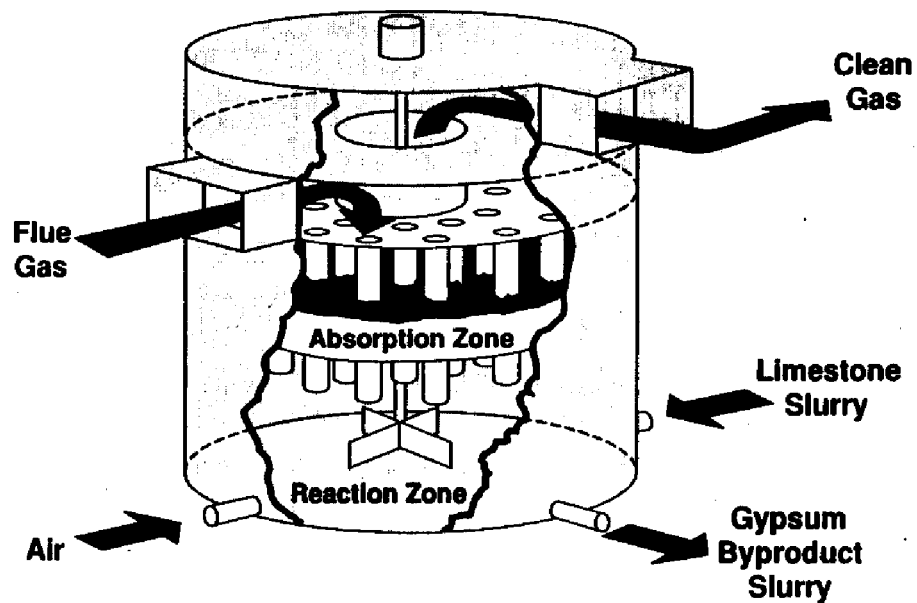
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FIGURE 1

## Chiyoda's Jet Bubbling Reactor



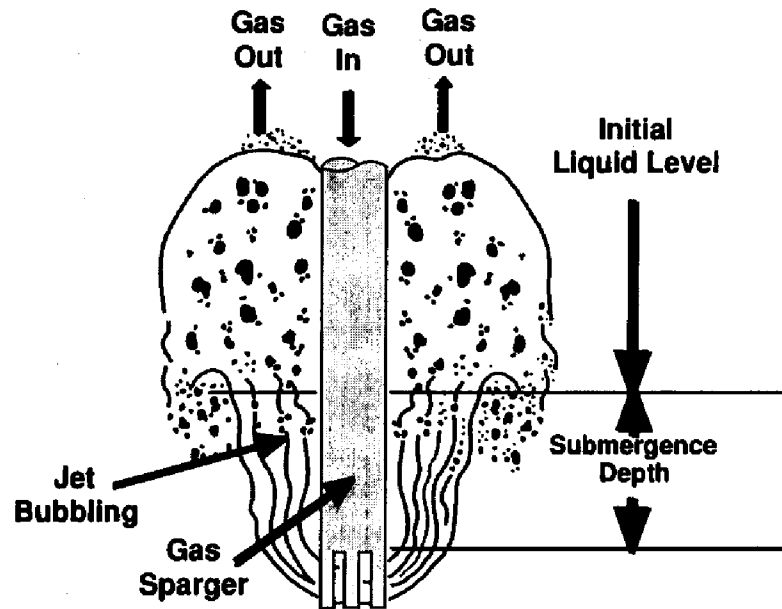
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FIGURE 2

# CT-121 Gas Sparger Action



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FIGURE 3

sedimentation, excavation, and raising of perimeter dikes continues on a regular basis during the active life of the stack. Process water is naturally decanted, stored in a surge pond and then returned to the CT-121 process. There is no blowdown or discharge from the Yates CT-121 process.

During normal operation of the FGD system, the amount of SO<sub>2</sub> removed from the flue gas is controlled by varying the JBR pressure drop ( $\Delta P$ ) or slurry pH. However, changing  $\Delta P$  is easier and quicker to respond to changing conditions since it is done by adjusting the JBR liquid level. Higher liquid levels result in increased SO<sub>2</sub> removal because of increased contact time between the incoming flue gas and the scrubbing slurry. The pH can also be varied to affect SO<sub>2</sub> removal with higher pH resulting in increased removal efficiency. Boiler load and flue gas SO<sub>2</sub> concentration also affect removal efficiency, but are less controllable.

One of the most unique aspects of the CT-121 installation at Plant Yates is the wide use of fiberglass reinforced plastics (FRP) in several of the vessels to avoid the traditional corrosion damage associated with closed-loop FGD systems. Two of the vessels (the JBR and the limestone slurry storage tank) were constructed on site since their large size precluded shipment. The JBR inlet transition duct, where the flue gas is cooled prior to contacting the sparger tubes as a wet-dry interface, is also made completely of FRP. The inlet transition was discovered to be an area susceptible to erosion during high ash testing but homogeneous appliqué filler materials, Duomar® and Duomix®, now offer robust protection to exposed FRP surfaces at Plant Yates. A distinct advantage of the FRP construction was that it eliminated the need for a flue gas prescrubber, traditionally included in flue gas scrubber systems to remove chlorides that cause significant corrosion in alloys (fiberglass is mostly unaffected by inorganic acid attack and chlorides).

### **III. PROJECT OBJECTIVES**

To evaluate the effectiveness of the Yates CT-121 design advances, the following test objectives of the two year demonstration program were established:

- Demonstrate long-term reliable operation of the CT-121 FGD system;
- Evaluate particulate removal efficiency of the JBR and system operation at normal and elevated particulate loadings;
- Correlate the effects of pH and JBR gas-side pressure drop ( $\Delta P$ ) on system performance;
- Correlate the effect of limestone grind on system performance;
- Evaluate the impact of boiler load on system performance;
- Evaluate the effects of alternate fuels and reagents on system performance;
- Evaluate equipment performance and construction material reliability; and
- Monitor solids properties, gypsum stack operation and possible impacts of the gypsum stack on ground water.

Many of these objectives were investigated during this last trimester of the second phase of the demonstration project, also known as the High-Particulate Auxiliary Test block. Two of the test periods in this test block provided data relevant to the focus of this paper:

- High-Particulate Alternate Coal Tests which evaluated scrubber performance under elevated particulate loading conditions while burning high-sulfur (3.4%) coal;
- High-Particulate Alternate Limestone Tests which evaluated an alternate limestone reagent source, while under elevated particulate loading, burning low-sulfur coal (1.2 % S).

Particulate and air toxics removal testing were also conducted during the Alternate Limestone testing. The data from the parametric portion of this test period was regressed to develop a predictive performance model for the conditions at which the testing was conducted, since these conditions are the most likely scenario for post-demonstration operation

#### **IV. RESULTS**

The CT-121 scrubber at Plant Yates continued to prove itself a very viable and cost effective technology for use in Clean Air Act, Title IV compliance. It exhibited excellent availability, maintained greater than 97% limestone utilization, and demonstrated the ability to exceed 98% SO<sub>2</sub> removal efficiency with high sulfur coal, while at maximum boiler load. The flexibility of the CT-121 process was also demonstrated through the use of a wide range of coals, varying from 1.2% to 4.3% sulfur content.

##### **Operating Statistics**

The duration of the demonstration, including the startup and shake-down phase, was 27 months, or approximately 19,000 hours. The low-particulate test phase (including shake-down) consisted of 11,750 hours, during which time the scrubber was operated for 8,600 hours. The remaining 7,250 hours of the demonstration included 5,510 hours of operation at elevated particulate loading. Complete operating statistics for the entire demonstration project are detailed in Table 1. The "high-ash" test period actually consisted of a high-ash loading period (during the Parametric Test block) in which the ESP was completely deenergized, and a moderate-ash loading period (during the Long-Term and Auxiliary Test blocks) during which the ESP was partially de-energized to simulate a more realistic scenario: a CT-121 retrofit to a boiler with a marginally performing particulate collection device. The moderate-ash loading condition resulted in better availability than did the high-ash loading condition.

	<b>Low-Ash Test Phase</b>	<b>High-Ash Test Phase</b>	<b>Demonstration Project Duration (Cumulative)</b>
Total Hours in Test Period	11,750	7,250	19,000
Scrubber Available Hours	11,430	6,310	18,340
Scrubber Operating Hours	8,600	5,210	13,810
Scrubber Called Upon Hours	8,800	5,490	14,290
<b>Reliability<sup>1</sup></b>	<b>0.98</b>	<b>0.95</b>	<b>0.96</b>
<b>Availability<sup>2</sup></b>	<b>0.97</b>	<b>0.95</b>	<b>0.97</b>
<b>Utilization<sup>3</sup></b>	<b>0.73</b>	<b>0.72</b>	<b>0.75</b>

1. Reliability = Hours scrubber operated divided by the hours called upon to operate.

2. Availability = Hours scrubber available divided by the total hours in the period.

3. Utilization = Hours scrubber operated divided by the total hours in the period.

**Table 1. Summary of Operating Statistics**

### **Effect of Inlet SO<sub>2</sub> Concentration**

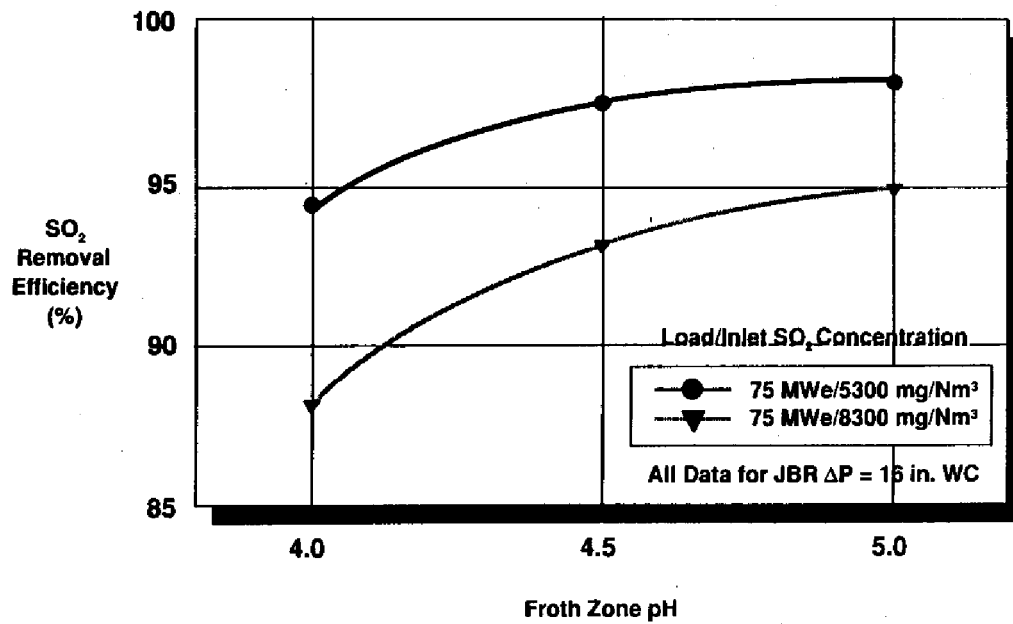
The SO<sub>2</sub> removal efficiency of the scrubber was measured under five different inlet SO<sub>2</sub> concentration ranges; three during this most recent testing. The coal burned by Unit 1 for a majority of the testing was a blend of Illinois No.5 and No.6 bituminous coal that averaged 2.4% sulfur (as burned), except for a brief, unplanned period when 3.0% sulfur coal was burned. A 4.3% sulfur bituminous coal was burned during the Low-Particulate Alternate Coal Test block, and a 3.8% sulfur coal was burned for the High-Particulate Alternate Coal Test block. The High-Particulate Alternate Limestone Test (last test of the demonstration project) coincided with Plant Yates' compliance-driven transition to a low sulfur coal (approximately 1.2% S). This provided the scrubber project an opportunity to evaluate a fifth coal source.

The effect of inlet SO<sub>2</sub> concentration on SO<sub>2</sub> removal efficiency is quite significant. Figure 4 illustrates the decrease in SO<sub>2</sub> removal as inlet SO<sub>2</sub> concentration increased for the coal sources evaluated. Performance of the scrubber was outstanding during the low-sulfur coal burn. It should be noted that the low-sulfur coal tested limited the JBR pH to a maximum of 3.8 because of Aluminum-Fluoride-inhibited limestone dissolution (Al-F blinding). The Al-F blinding stems from the low-ionic strength of the scrubbing liquor, the elevated ash loading to the JBR and the coal trace metals concentrations. A maximum operating pH of 3.75 was chosen to ensure that near-complete limestone utilization was maintained in the scrubber. The test data from 1000 ppm (inlet SO<sub>2</sub> concentration) operations indicates that SO<sub>2</sub> removal efficiency did not decline at a slightly lower pH.

The evaluation of five different inlet SO<sub>2</sub> concentrations demonstrates the flexibility of the CT-121 process as well as its exceptional SO<sub>2</sub> removal capability, even when burning fuels with a very high sulfur content. This is even more impressive considering that the maximum designed sulfur



## High-Sulfur Coal Effects on SO<sub>2</sub> Removal Efficiency



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FIGURE 4

content for the demonstration unit was only 3.0%, and that this limit was exceeded by 43% in one test period. Other test data shows that even higher SO<sub>2</sub> removal efficiencies are achievable at higher pH values.

### **Particulate Removal Efficiency**

Because of the torturous path taken by the flue gas during treatment in the JBR, an effort was made to quantify particulate removal. Consequently, the ability of the CT-121 process to remove flyash particulate was evaluated several times throughout the demonstration. Particulate loading measurements were made at the inlet and outlet of the scrubber under three different conditions of inlet mass loading, summarized in Table 2. The discussion here will focus on the particulate removal capabilities of the scrubber under only the moderate-ash loading conditions.

<b>Condition</b>	<b>ESP Energization</b>	<b>ESP Collection Rate</b>	<b>ESP Outlet~JBR Inlet <i>JBR Inlet Mass Loading (lb/MMBtu)</i></b>
<i>1</i>	Full	High	<i>Low ( 0.02-0.10)</i>
<i>2</i>	Partial	Moderate	<i>Moderate (0.20-0.50)</i>
<i>3</i>	Off	Low	<i>High ( 5.00-5.50)</i>

**Table 2. ESP Configuration during Particulate Testing**

Measurements of particulate removal across the JBR (Condition 2, Table 2) were made near the minimum and maximum nominal boiler loads (50 and 100 MW), and at low and high JBR ΔP settings (10 and 18 in.WC). The test conditions and results are shown in Table 3. As shown in Table 3, at all tested inlet particulate loadings, boiler loads, and JBR pressure drops the JBR exhibited excellent particulate removal efficiency, ranging from 97.7% to 99.3%.

Although the outlet particulate loading varied from 0.005 to 0.029 lb/MMBtu, analytical results indicate that from 20 to 80 percent of outlet particulate is sulfate (SO<sub>4</sub>). Based on the calcium analyses performed on the same material, it is believed that the measured sulfate originated from gypsum carryover and acid mist carryover, so it is scrubber-generated. This finding reduces the estimate of actual ash mass loading at the outlet of the scrubber (actual fugitive emissions) to approximately 70% of the amount captured, measured and recorded during outlet testing.

Test I.D.	Approximate ESP Efficiency (%)	JBR $\Delta P$ (in. WC)	Boiler Load (MW)	JBR Inlet Mass Loading (lb/MMBtu)	JBR Outlet Mass Loading <sup>1,2</sup> (lb/MMBtu)	JBR Removal Efficiency (%)
AL2-1	90	18	100	1.288	0.029	<b>97.7</b>
AL2-2	90	10	100	1.392	0.010	<b>99.3</b>
AL2-3	90	18	50	0.325	0.005	<b>98.5</b>
AL2-4	90	10	50	0.303	0.006	<b>98.0</b>

<sup>1</sup> Federal U.S. NSPS is 0.03 lb/MMBtu for units for which construction began after 9/18/78

<sup>2</sup> Plant Yates Unit 1's permitted emission limit for existing units is 0.24lb/MMBtu (40% opacity)

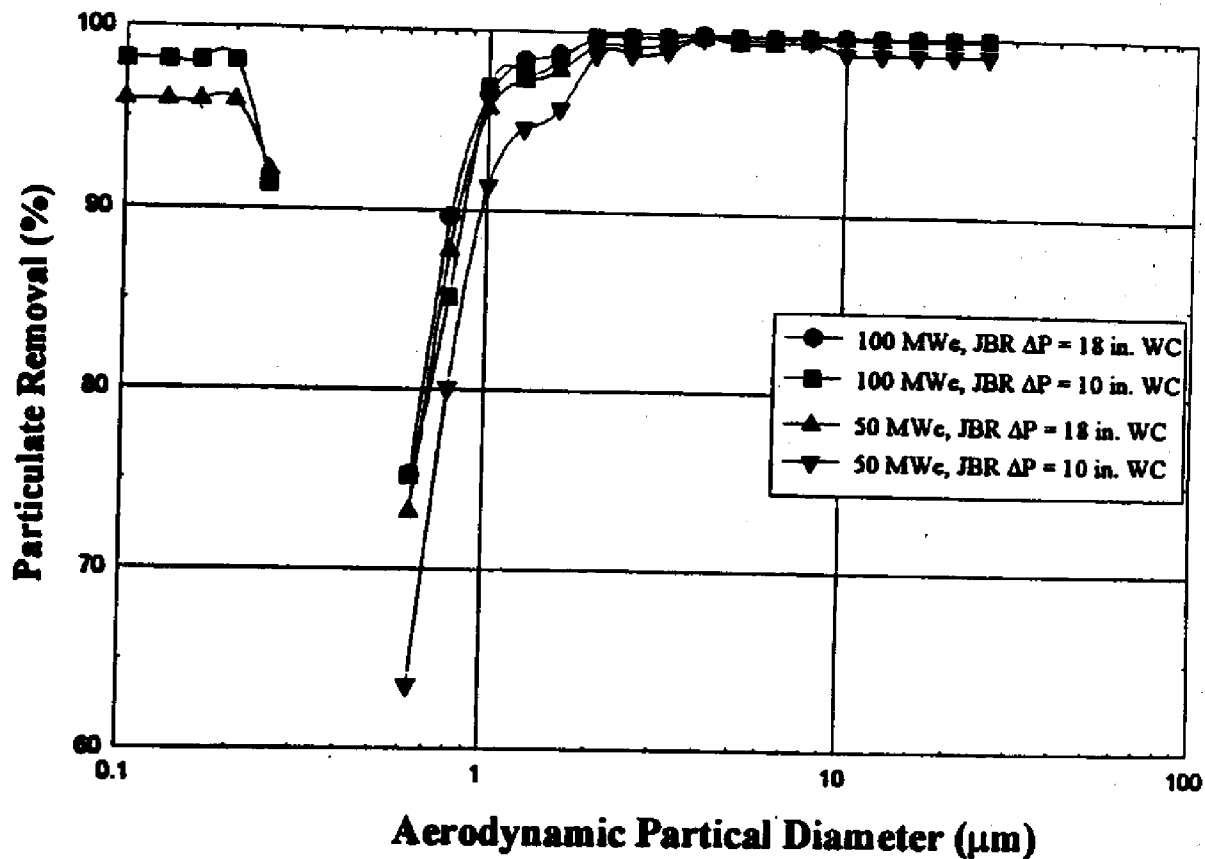
**Table 3. Particulate Removal Testing - Summary of Results**

### **Particulate Removal Efficiency by Particle Size**

The particle size distribution of the scrubber inlet and outlet particulate matter was measured at all four test conditions as shown in Table 3. The results of these analyses indicate that excellent particulate removal efficiency occurred in most of the measured size ranges (cut-points). Figure 5 illustrates the particulate removal efficiency of the scrubber by comparing inlet and outlet mass loading at different particle size cut-points (shown using a logarithmic scale). The inlet data were combined for both 50 MW tests and for both 100 MW tests to simplify the plots since inlet conditions were identical in each case.

As observed in the plots, the 100 MW case showed better particulate removal efficiency than the 50 MW case at most cut-points. One possible explanation is based on the mechanism of particulate removal in the scrubber. Because the velocity of flue gas is higher at higher loads, the particulate has more momentum and is more likely to come into contact with the wet/dry interface as each flue gas "bubble" rises through the slurry.

As was reported during earlier particulate removal tests, and again observed in Figure 5, the best removal efficiencies were observed for particle sizes greater than 10 $\mu$ m. At all test conditions, there was greater than 99% particulate removal efficiency of particles in this size bin. In some cases, efficiency exceeded 99.99%. As the particle size decreased, there was a drop in observed particulate removal efficiency, but over 90% efficiency was observed at all particle sizes between 1 $\mu$ m and 10 $\mu$ m. Between 0.5 $\mu$ m and 1 $\mu$ m, the particulate removal dropped to sometimes negligible values. In this range, it is believed that acid mist carryover offset the ash particulate removal, resulting in poor particulate removal values. Analyses of the outlet catch indicated that an average of 30% of the outlet particulate can be attributed to gypsum and acid mist carryover. Below about 0.5 $\mu$ m, the particulate removal efficiency increased to above 90%. Also observed in Figure 7 was a higher particulate removal efficiency at the higher JBR  $\Delta P$  values. This increase in removal efficiency ranged from 1 decade (90%), at the largest particle sized, to less than 1/10th of



### Moderate-Ash Scrubber Particulate Removal Efficiency

FIGURE 5

a decade (10%) at the 0.5 $\mu$ m cut-point. The increased particulate removal at the higher JBR  $\Delta$ P in this size range results from a deeper sparger tube submergence depth and therefore, a longer gas-phase residence time allowing more opportunity for the particulate to be captured in the slurry.

## **V. AIR TOXICS TESTING**

The Yates CT-121 ICCT Project had two opportunities to measure its air toxics removal potential (also referred to as HAP or hazardous air pollutants). In 1993, Yates was chosen by the DOE as one of its eight coal-fired sites for an air toxics study<sup>1</sup> conducted on EPA's behalf in support of Clean Air Act Title II requirements for subsequent health risk determinations. In late 1994, the Yates ICCT Project expanded its scope of work to duplicate portions of that 1993 effort, in an attempt to validate the DOE's 1993 results. The results are both interesting and mutually supportive. However, the fossil fuel sources between the two tests were radically different and an exact comparison of results can not be easily made.

In 1993, the DOE was hoping to investigate three issues;

- Air toxics characterizations/penetrations in fossil fuel systems (fuel/boiler/ESP);
- Air toxics removal potential for postcombustion equipment (ESP/wet scrubber);
- Air toxics emissions factors in lb/10<sup>12</sup> BTU.

From the 1993 results, the DOE concluded that:

- As much as 99% of the HAPs of interest are in the particulate phase;
- Specie removal across the ESP was proportional to total particulate removal;
- Uncertainty was high because most measurements were near the minimum analytical detection limits;
- Special difficulties were encountered with selenium, mercury and chromium (Cr<sup>6+</sup>).

The 1994 air toxics sampling conducted as part of the ICCT Project by Radian at Plant Yates was performed to address the technical difficulties encountered during the 1993 tests; specifically:

- Selenium sampling and analysis;
- Mercury partitioning and speciation;
- Flyash penetration of the FGD process; and
- Source apportionment (origin of exiting and particulate matter),

as well as to be able to compare emissions and removals from a radically different coal source within the same boiler/ESP/scrubber flue gas pathway.

In comparing the results of the two efforts from a macro-perspective, several observations emerge that may effect the use of air toxics data in further rulemaking and health risk determinations:

- The 1993 effort saw significantly more measurement error than the 1994 effort;
- The Chiyoda CT-121 JBR is highly efficient at HAP removal;
- Sampling is very sensitive to ANY error (e.g.: Contamination) at these near-minimum detection level measurements; and
- Source apportionment identifies a significant emission contribution from particulate generated within the wet scrubbing process.

The uncertainty in the 1994 testing data is generally lower than that of the 1993 testing data (i.e., sampling procedures improved). Secondly, due to the larger uncertainty evident in some species in 1993, the accuracy of any calculated emission factors would likewise be suspect. It is apparent from the data that some species can be measured with much lower uncertainty than others. Fairly low uncertainty were found for arsenic, vanadium, and lead. Conversely, antimony, chromium, manganese, and nickel all had unacceptably large measurement confidence intervals, sometimes the confidence interval was 10 times larger than the measurement itself. Calculated removal efficiencies from the 1994 tests are shown in Figure 6. It is prudent to remind ourselves that extrapolation of admittedly uncertain data does not lend itself to producing certain results for emission factor estimation or subsequent health effects determinations. Caution should be emphasized in the use of these and any similar air toxics measurement data.

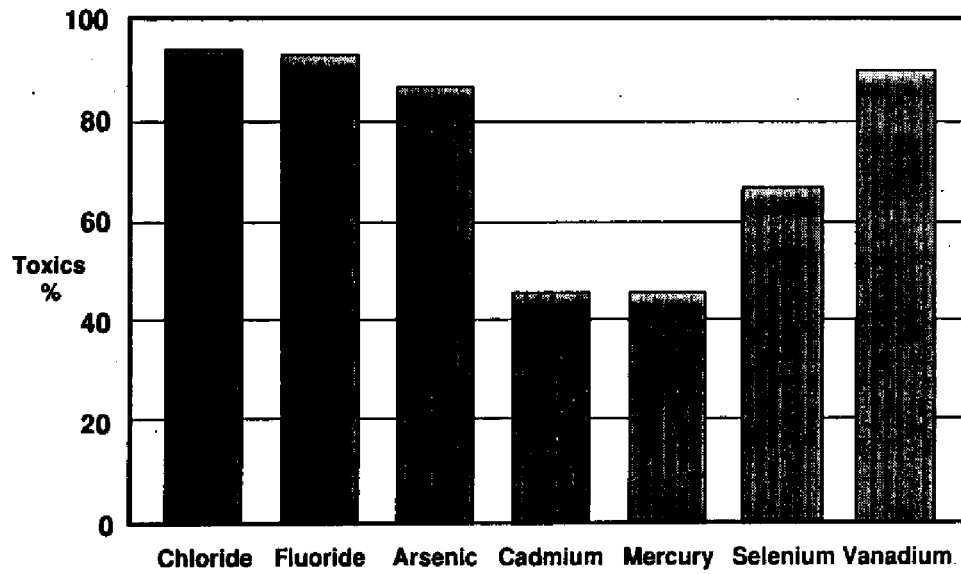
## **VI. GYPSUM QUALITY**

The gypsum stacking area at Plant Yates had three separate cells for segregated impoundment; a “clean” gypsum stack area, a gypsum/ flyash stack area, and a recycle water pond. During Phase I (the low-ash test phase) of this demonstration project, the “clean” gypsum stack was used to dewater and store the pure-gypsum byproduct; decanted clear process water was collected in the common pond area and returned to the process. There was no blowdown, discharge or water treatment of scrubber process water. During the high-ash test phase (Phase II), the segregated gypsum/ash area was used for stacking the ash/gypsum mixture. Since these stacks are physically separated “cells”, the original “clean” gypsum stack then, sat idle during the later ash/gypsum phase of testing.

The gypsum slurry deposited in the both areas was originally with a high chloride content, due to the closed loop nature of the scrubber's operation, with liquid phase chloride concentrations calculated to be as high as 35,000 ppm at equilibrium. Because of these high chloride concentrations, any slurry-deposited gypsum solids would normally require washing in order to satisfy requirements of the gypsum wallboard or cement manufacturing industries. Core samples of the “clean” stack that were taken after the stack had been idle for over a year indicated a surprising result: the chloride concentration in the gypsum had decreased from about 6000 ppm, measured 3 months after Phase I completion, to less than 50 ppm less than one year later. Table 4 presents chloride data for the gypsum stack.

# Air Toxics Removal

Yates CT-121 Project (JBR Components Only)



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FIGURE 6

There are two likely reasons for this decrease in chloride concentration in the gypsum in the "clean" gypsum stack. The first is that the rainfall that occurred over the idle year washed the gypsum and decreased the chloride concentration. The rate of chloride decrease over time, or as a function of rainfall, was not measured because this was an unplanned (and at the time, unknown) benefit of the gypsum stacking technique. The other reason lies in the fact that a majority of the chloride content in the gypsum solids is due to the chlorides in the water entrained in the gypsum solids. Core samples from the gypsum stack typically indicated that the solids content was approximately 83 wt.% on average shortly after the stack was idled. After one year, the solids content had increased to an average of 90 wt.% at a depth of 3 feet. Although this decrease in entrained water played some role in decreasing the chloride concentration in the gypsum, it is likely that rainwater washing of the stack was the predominant cause of the decrease in chloride concentration. This is further evidenced by the data presented in Table 4 that shows free moisture did not decrease at the 6 foot level, although chloride concentration did.

Of interesting note, was the 1996 issuance of a Plant Food Permit to Georgia Power that will allow the unrestricted sale of ash-free gypsum from the Yates Project to meet the unfilled demand for agricultural gypsum of 1 million+ ton/year in Georgia alone.

<b>Dike</b>	<b>Inactive Period</b>	<b>Sample Depth (ft)</b>	<b>Chloride (ppm)</b>	<b>Moisture (%)</b>
West	>90 days	4	<b>930</b>	16.0
	>90 days	8	<b>7610</b>	17.5
	>90 days	9.5	<b>5720</b>	17.7
	>90 days	14.5	<b>5540</b>	15.1
	<b>&gt;400 days</b>	1	<b>60</b>	8.1
	<b>&gt;400 days</b>	3	<b>40</b>	9.2
	<b>&gt;400 days</b>	6	<b>20</b>	12.0
	>90 days	10	<b>5740</b>	14.5
	>90 days	13.5	<b>5610</b>	17.4
South	>90 days	16.5	<b>6710</b>	17.4
	<b>&gt;400 days</b>	1	<b>20</b>	8.0
	<b>&gt;400 days</b>	3	<b>20</b>	11.0
	<b>&gt;400 days</b>	6	<b>20</b>	18.3

**Table 4. Chloride and Moisture Levels in "Clean" Gypsum Stack decline over time**



## **VII. SUMMARY**

Chiyoda's CT-121 FGD process was very successfully tested at conditions far beyond design expectations. From an operating standpoint, the process was reliable, showed consistently high removals (SO<sub>2</sub>, particulate, air toxics), was energy efficient and reagent efficient. From a chemical engineering standpoint, the mass transfer interactions are robust and resilient, only limited at conditions far beyond design parameters. This would allow a designer / operator to install a cost effective CT-121 system that would give consistently excellent service, even in periods of difficult operating conditions.

1. "A Study of Toxic Emissions from a Coal-Fired Power Plant Utilizing an ESP While Demonstrating the ICCT CT-121 FGD Project," Radian Corporation, Final Report for U.S. DOE, Contract No., DE-AC22-93PC93253. June 16, 1994.